Monetary valuation of forest ecosystem services in China : A literature review and identification of future research needs

D'amato, Dalia

2016-01

D'amato , D , Rekola , M O , Li , N & Toppinen , A M K 2016 , ' Monetary valuation of forest ecosystem services in China : A literature review and identification of future research needs ' , Ecological Economics , vol. 121 , pp. 75 . https://doi.org/10.1016/j.ecolecon.2015.11.009

http://hdl.handle.net/10138/234701
https://doi.org/10.1016/j.ecolecon.2015.11.009

Monetary valuation of forest ecosystem services in China:

a literature review and identification of future research needs

Key words: Ecosystem services; Forest, Plantations; Monetary valuation; Non-market values; China.

D'Amato, D., Rekola, M. , Li, N. and Toppinen, A.

University of Helsinki - Department of Forest Sciences, Latokartanonkaari 7, 00014, Helsinki, Finland.

Corresponding author: D'Amato Dalia; email: dalia.damato@helsinki.fi

Abstract

We propose a review of empirical studies dealing with the monetary valuation of forest ecosystem services in China. The analysis focuses on: assessing methodological differences between studies; highlighting the variation of monetary values across different ecosystem service types; and identifying and discussing future research needs. Based on a systematic search, our data set consists of 12 studies published in peer-reviewed journals in English, dealing with 72 forest ecosystem services. Our results suggest that domestic literature is affected by elusive categorization of ecosystem services and methodological inconsistencies. The wide variation in monetary values of Chinese forest ecosystem services, a phenomenon also observed in global level reviews, can be partially explained by the methodological heterogeneity of the studies. Future research could benefit from a strengthened and more standardized methodological approach, drawing from relevant methods and indicators employed in the reviewed domestic articles, as well as from insights and solutions proposed in the international empirical and conceptual literature. The exceptional forest restoration policy landscape coupled with the increasing establishment of commercial plantations offer important research opportunities for monetary valuation in China. Efforts should be directed towards assessing marginal values of ecosystem services in land-use changes over time, and benefit flows among different stakeholders.

1 Introduction

China is a globally interesting example of how changing forest resource management plays out in supplying ecosystem services (ES). The country is the most rapidly-developing and resource-demanding economy. Round wood production, for example, has increased from 20 to 144 million m^3 between 1950 and 2013 (FAO 2015). China is concurrently also an experimental field for its reforestation reforms, which are of unique degree and scope worldwide (e.g. Xu et al., 2006). The use of forest resources in the past decades, a consequence of large domestic demand, almost exhausted the country's natural forest stocks. Overharvesting has led to structural changes and compromised in many locations the functioning of forest ecosystem services, such as water regulation. In 1998, a series of destructive flash flooding and drought events occurred in almost all major river basins, causing damages of RMB 248 billion (approximately USD 30 billion), the loss of 4150 human lives and the displacement of millions of people (Durst et al., 2001; Liu et al., 2008; TEEB, 2012, p. 46). The Chinese government then acknowledged that deforestation and excessive logging had resulted in increased runoff, soil erosion and the siltation of waterways. A range of regulations, policies and economic instruments for forest resource management have been introduced (Yukuan et al., 2010) to restore the hydrogeological regime and enhance carbon uptake under the threat of climate change (Yang et al., 2010). Logging bans have been imposed in State-owned forests in the upper reaches of the Yangtze River and the middle and upper reaches of the Yellow River to halt the deterioration of the natural environment.

Several economic incentives for reforestation, such as eco-compensation schemes, have been implemented at different administrative scale (Bennett, 2009; Madsen et al., 2010; Xu et al., 2006; Zhen and Zhang, 2011). Nation-wide programmes such as the 'Grain to Green Program', the 'Natural Forest Protection Program' and the 'Wildlife Conservation and Nature Reserve Development Program' are in place, supported by regional programmes. The market-driven development of fast-growing and high-yield timber plantations has been promoted through the 'Forest Industrial Base Development Program' (Evans, 2009). These policy efforts have turned into outputs. Between the early 1970s and late 2000s, forest coverage has increased from 12% to 20.36% of the total forested area. There are currently 206.8 million ha of forests in China, over 30% of which are plantations (Hansen et al., 2014, p. 155). China has in fact established the largest plantation area in the world, and – in accordance with the global trend – more plantations are planned in the future (Bauhus et al., 2010, p. 4). The five major tree species are *Larix, Pinus tabulaeformis, Pinus massoniana, Cunninghamia lanceolata,* and *Populus* (Zhao and Zhou, 2005), and quality and quantity of these species vary across the country. Based on the fourth forest inventory in China (1989–1993), *P. Massoniana* occupies the largest area, corresponding to 14.3 million ha. *Larix* and with *C. Lanceolata* occupy the second (9.2 million ha) and third largest (9.1 million ha) areas. *Larix* has the highest total volume (871 million m^3) and the greatest variations in biomass and Net Primary Production (NPP), ranging from 2.7 to 135.37 Mg per ha and 0.9 to 10.3 Mg per ha per year. On the other hand, *P. Massoniana* has the smallest total volume of 430 million m^3. Biomass and NPP of *Populus* varied less across the country, and they were respectively 50 Mg per ha and 7–8 Mg per ha per year. Available statistics, however, contain consistent variation and uncertainty on plantations' condition and productivity (Brown, 2002; Fang et al., 2001; Turnbull, 2007). According to and Xu et al., 2000 the most productive *Eucalyptus* and exotic pines plantation in China has relatively low productivity compared to plantations elsewhere.

Non-native monocultures have received critiques for their negative impacts on biodiversity and ecosystem services, such as for example water supply and regulation, soil maintenance, nutrient cycling (Pawson et al., 2013; Turnbull, 2007; for a review, D'Amato et al., 2015). ES valuation has a role to play in raising awareness and supporting decision-making regarding forest management and conservation policies in China (Liu and Costanza, 2010; Zhang et al., 2010a). Forest ecosystem services and their monetary values have received considerable attention both at the national and local scale (Zhang et al., 2010a). There is, however, a gap in systematically reviewing results of existing monetary valuation studies, especially in light of the problems and challenges raised in influential conceptual or empirical studies of regional or global scope: the ambiguous classifications of ecosystem services; the question of methodology and validity; and the implications and applications of monetary valuation for future research (Bateman et al., 2011; Ninan and Inoue, 2013; Ojea et al., 2012; Turner et al., 2010).

The contribution of this study is to provide a systematic review of relevant empirical studies dealing with the monetary valuation of forest ecosystem services in China. We particularly focus on the following questions: 1) what are the methodological approaches employed; and 2) what are the main findings from identified literature, including the range of monetary values across different services. In the discussion we address the existing research gaps and future research needs. Being aware of the numerous technical and conceptual limitations of any monetary valuation process (e.g. Gómez-Baggethun and Pérez, 2001; Luck et al., 2011; Spangenberg and Settele, 2010; Wilson and Howarth, 2002), we believe that expressing the value of ecosystem services in monetary form can represent a relevant tool — supported by a plurality of other values — to argue the crucial importance that ecosystem services play in human social and economic well-being, and to support the policy debate regarding exploitation versus sustainable use (de Groot et al., 2012; Turner et al., 2010), particularly in the context of emerging countries.

2. Methods and data

This research builds upon a systematic literature review of previous studies, conducted by following the guidelines of Khan et al. (2003): framing the research questions; identifying relevant work; assessing the quality of studies; summarizing the evidence; and interpreting the findings. The research question was framed as 'the monetary valuation of ecosystem services in China, either in natural, plantation or urban forests'. We only considered peer-reviewed journal papers published in English, using Web of Science as a database. Keywords for the search included a combination of the following: 'Ecosystem services' or 'Environmental benefits'; and 'Economic valuation' or 'Monetary valuation' or 'Non-market values'; and 'China' or 'Chinese'; and 'Forests' or 'Plantations'. We excluded any paper dealing with ecosystems other than forests. We only accepted papers which provided monetary value for one or more ecosystem service(s); information on the location and size of the study area; and information concerning the methodological approach employed. Valuation methods accepted were market price, the cost-based (e.g. avoided cost/damage) method, contingent valuation and benefit transfer. Choice experiment would also have been an acceptable method, but no study was found that employed this methodology. For the classification of valuation methods, we referred to Bateman et al. (2011) and Kettunen and ten Brink (2013, pp.44-45).

The described filtering process produced a list of 12 relevant articles and we believe we have intercepted all the relevant peer reviewed papers published in English dealing with this research topic. The publication year of the reviewed papers ranged between 2000 and 2012. However, note that the number of unit of analysis is higher (72) than the number of papers, as most of the reviewed papers focused on several forest ecosystem services, employing more than one valuation method per ecosystem service and generating several monetary estimates. For each of the 12 studies, the following information has been coded: ecosystem services investigated; methodology employed to assess the ecological functions and monetary estimates; the monetary values estimated; and size of area under investigation. We classified each service according to the Millennium Ecosystem Assessment categories (MA, 2005): provisioning, regulating, cultural and supporting. In some studies we reviewed, the investigate ecosystem services were not named after the MA classification. Therefore, during our analysis, the ecosystem services investigated in the studies had to be re-named according to the corresponding MA category. For example, Xie et al. (2010) assessed, among others, the economic values of generic 'cultural' services, while Hu et al. (2008) estimated the value of 'cropland protection' performed by forests: it is not specified what ecological function or social values these categories include or refer to. We also created an extra category, named 'other' (see Table 1), including wider socio-economic benefits (the importance of these is discussed in Kettunen and ten Brink, 2013, Chapter 10) and bundled ecosystem services.

Our analyses particularly focus on regulating services, as these are most commonly the object of investigation in the reviewed papers. We analysed four macro-categories of regulating ecosystem services: hydrological services, carbon storage, soil conservation and nutrient cycling. Finally, we synthetized the methodological approaches and monetary estimates proposed by the reviewed papers. Most of the studies do not specify the currency year for the economic estimates. The publication year was then used for converting the monetary estimates from Chinese Yuan (RMB) to international USD (intUSD) for the year 2013 in the following manner (van der Ploeg et al., 2010): *IntUSD*= (*LCU**(*PPP2013*/*PPPt*))/PPP2013. Similarly, the original estimates available in US dollars (USD) were converted to international USD (intUSD) for the year 2013 in the following manner: *IntUSD*= (*USD**(*GDPdefl.2013*/*GDPdefl.t*))/*PPP2013*; where *LCU* is local currency; *PPP2013* is Purchasing power parity at year 2013 and *PPPt* is Purchasing power parity at the year of publication, *GDPdefl.2013* is the GDP deflator at year 2013 and *GDPdefl.t* is the GDP deflator at year of publication. The indexes for PPP and GDP were retrieved from The World Bank (2015) database. Many papers only provide the total monetary values of the forest area studied without giving the corresponding value per unit of area. We calculated and discussed the 'per hectare' estimates using the study area size reported by the papers, despite the possible inaccuracies that such a process might produce.

As only a limited portion of Chinese research is published in English, the majority of ecosystem services research in China is inaccessible to the global community because of the language barrier (Liu and Costanza, 2010). The core assumption behind this literature review is therefore that the existing peer-reviewed papers published in English are representative of the Chinese literature, possibly representing the highest cohort in terms of research quality.

3. Results

3.1 Ecosystem services and methodological approaches in the data

The studies listed in Table 1 present a wide variation in terms of geographical distribution, spatial scale and forest type. The studies focused on forest systems at the city, protected area, province or national level. Most regional studies focused on the eastern provinces. The forest types investigated were urban and natural forests, including pine and mixed forests. However, not all studies made a methodological distinction based on vegetation type.

Table 1 List of articles included in this review, including geographical scope, type and number of ecosystem services investigated.

Author	Geographical scope	Provisioning	Regulating	Cultural	Supporting	Other	No. of ES valuated	Method employed
Chen and Zhang, 2000	National	0	0	0	0	1	1	Benefit transfer
Guo et al**.,** 2001	Regional, Regional, Xingshan county	4	3	0	0	0	7	Market price and cost avoided
Guo et al., 2008	National (pine forests)	0	6	0	1	0	7	Market price and cost avoided
Hu et al., 2008	Local, Menglun	4	8	1	1	1	15	Benefit transfer
Jim and Chen, 2006	Local, Guangzhou (urban forest)	0	0	3	0	0	3	Contingent valuation
Li et al., 2006	Regional, Regional, Qinba mountains	0	5	0	1	0	6	Market price and cost avoided
Li et al., 2010	Local, Local, Shenzhen	2	4	1	1	0	8	Benefit transfer
Niu et al., 2012	National	0	5	0	0	0	5	Market price and cost avoided
Peng et al., 2008	Local, Nanjing (urban forest)	0	2	0	0	0	2	Market price and cost avoided
Xie et al., 2010	Local, Local, Beijing	3	4	1	1	2	11	Market price and cost avoided
Xue and Tisdel, 2001	Regional, Regional, Changbaishan mountain	0	6	0	0	0	6	Market price and cost avoided
Zhang et al., 2010b	Local, Local, Beijing	1	0	0	0	0	1	Market price and cost avoided
Total		**14**	**43**	**6**	**5**	**4**	**72**	

The number of ecosystem services investigated is different across the reviewed articles, ranging from a minimum of 1 to a maximum of 15 in a single paper (Table 1). Importantly, the studies deal mostly with regulating ecosystem services, as nine out of twelve papers evaluate at least one regulating service. Five papers dealt with provisioning services, four papers with cultural services and 5 papers with supporting services. Note that supporting services are usually not directly valuated as they are reflected in the other three categories of ecosystem services. Finally, three papers dealt with wider socio-economic benefits and bundled ecosystem services (categorized as ‘Other’ in Table 1). The most common services investigated are hydrological services such as water supply and regulation (totalling a presence rate of 75% in the reviewed papers), climate regulation (75%), soil maintenance and erosion control (67%), nutrient cycling (50%) and air quality regulation (42%) (Figure 1).

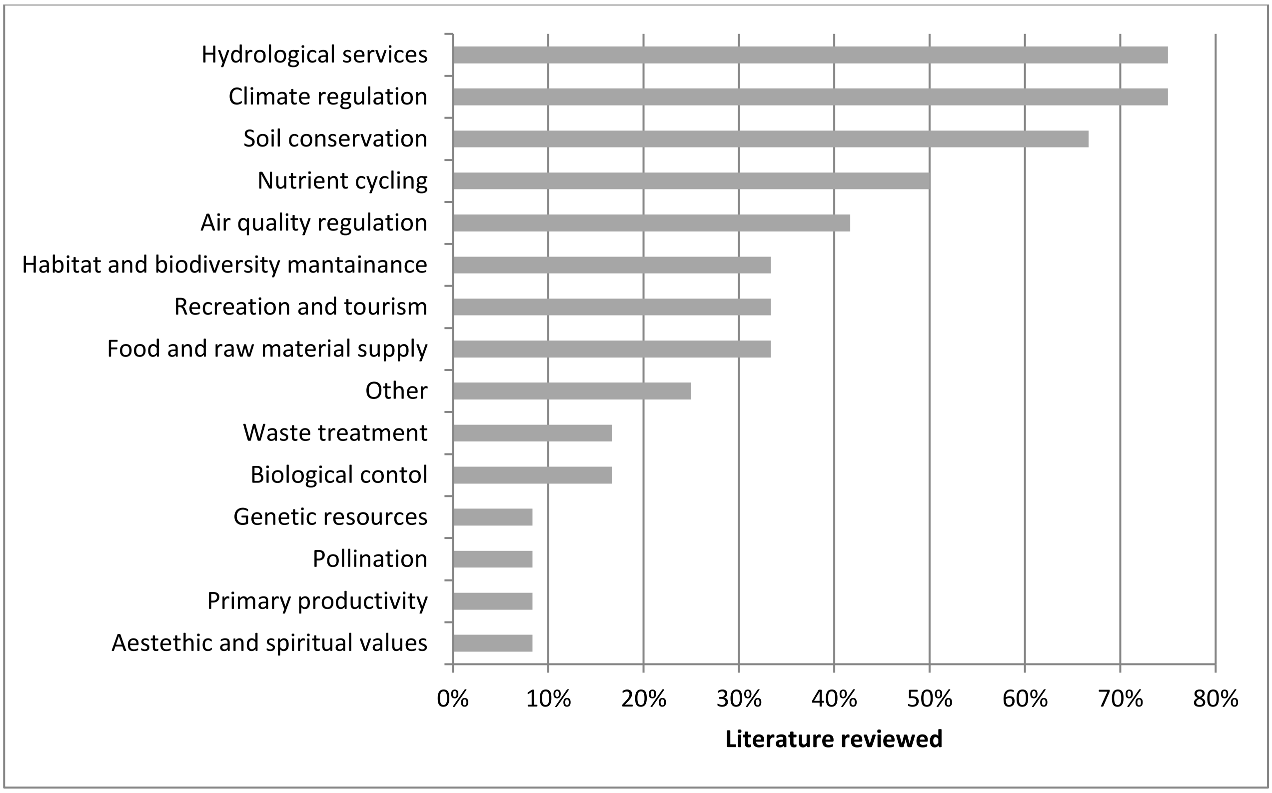

Figure 1 Occurrence of ecosystem service categories (MA, 2005) in the reviewed literature.

Following the monetary coefficients for global ecosystem services proposed by Costanza et al. (1997), three papers employed benefit transfer to estimate the value of ecosystem services in Chinese forests and were also the only papers addressing temporal changes in ecosystem services values (Chen and Zhang, 2000; Hu et al., 2008; Li et al., 2010). For example, a regional case study in Menglun, Southwest China (Hu et al., 2008) assessed the land-use change occurring in Menglun over an 18-year period. The monetary values of the local land-use types were estimated based on values given by Costanza et al. (1997) for a similar land-use type. Land-cover changes in Menglun resulted in a loss of ecosystem functions estimated at USD 11.427 million (a change of 27.73%). In a similar fashion, Li et al. (2008) calculated that from 1996 to 2004 land-use change of forest ecosystem services produced a decrease in the total economic value from 2776 to 2544.7 million RMB. The main challenges of benefit transfer are estimate transferability, which assumes an acceptable degree of similarity between the original site and the secondary site in terms of ecological, cultural, demographic and economic characteristics (Riera et al., 2012).

Other papers (Table 1) employed the market price method to produce a general approximation of the economic value of provisioning services and cultural services, such as recreation and tourism. Benefits that are not captured by the markets can be valued in monetary terms using non-market valuation methods. Cost-based methods (i.e. avoided cost or damage) are particularly suitable for approaching regulating services (de Groot et al., 2012; Kettunen and ten Brink, 2013). These methods estimate the monetary value of ecological functions performed by local ecosystems using the cost of replacing such functions with artificial alternatives or surrogate prices. For example, the value of erosion control by forests can be estimated using the cost of replacing this service with artificial water reservoirs.

For each reviewed paper we summarized authors and location; methods employed to assess ecological functions; methods employed for estimating monetary values; original estimates for the total study area (Mill. RMB or Mill. USD); size of forested, and total study area; and estimates per hectare (IntUSD 2013) (Tables 2a, b, c, d).

Table 2a Reviewed studies dealing with hydrological services, including their methodology, monetary value and size of study area.

Authors and geographical scope	Ecological functions assessment	Valuation method	Original estimate for study area ($x10^6$)	Forested / Study area (km^2)	Estimate per hectare (Int USD 2013)
Guo et al., 2001 **Regional, Regional, Xingshan county**	Difference between precipitation and evapotranspiration	Market price of hydroelectricity (1997)	RMB 54.7	1070/2316	186
Guo et al., 2001 **Regional, Xingshan county**	Difference between precipitation and evapotranspiration	Market price of water	RMB 3.59	1070/2316	12
Guo et al., 2008 **National (pine forests)**	Difference between precipitation and evapotranspiration	Cost avoided for water reservoir	RMB 32042.836 – 34508.4659**	NA/21900	4586–4938 **
Guo et al., 2008 **National**	Difference between precipitation and evapotranspiration	Market price of water			
Hu et al., 2008 **Local, Menglun,**	Land-use database	Benefit Transfer (Costanza et al., 1997)	USD 2.987-3.107***	NA/334	100–104
Hu et al., 2008 **Local, Menglun**	Land-use database	Benefit Transfer (Costanza et a.l. 1997)	USD 1,242-1,253***	NA/334	41–42
Li et al., 2006 **Regional, Regional, Qinba mountains**	Water interception by canopy, litter and soil	Cost avoided for water reservoir	RMB 2265.682	87089	90
Niu et al., 2012 **National**	Amount of service performed*	Market price*	RMB 4000000	NA/2176986	5241
Peng et al., 2008 **Local, Nanjing (urban forest)**	Runoff reduction by vegetated land versus non-vegetated land	Cost avoided for water reservoir	RMB 3.44	97/242	111
Li et al., 2010 **Local, Local, Shenzhen**	Land-use database	Benefit Transfer (Costanza et al., 1997)	-	NA/1900	632–606
Xie et al., 2010 **Local, Local, Beijing**	Ratio of rainfall interception to rainfall	Cost avoided for water reservoir	RMB 2757.27	10500/16807	792
Xie et al., 2010 **Local, Local, Beijing**	Ratio of runoff to rainfall	Market price of water	RMB 331.92	10500/16807	95
Xue and Tisdel, 2001 **Regional, Regional, Changbaishan mountain**	Difference between precipitation and evapotranspiration	Cost avoided for water reservoir	RMB 156.14	1670/1964	341

Zhang et al., 2010b **Local, Local, Beijing**	Monthly precipitation and surface runoff	Market price of water	RMB 315.33	9175	103
Zhang et al., 2010b **Local, Local, Beijing**	Interception by canopy and litter	Cost avoided for water storage	RMB 2770.4	9175	910
Zhang et al., 2010b **Local, Local, Beijing**	Interception by soil	Cost avoided for water storage	RMB 2147.56	9175	705

*Based on research station observations, national statistics and published data

**Values refer to periods 1996–2000 and 2001–2005

*** Value refer to period 1988–2006

Hydrological services

Several methods are employed to approximate the ecological functions of water interception and retention. Some authors calculated water retention with an input-output approach, by considering the ratio of runoff to rainfall or the difference in precipitation and evapotranspiration (Guo et al., 2008; Xie et al., 2010; Xue and Tisdel, 2001). Others calculated water retention as a function of canopy, litter and soil interception (Li et al., 2010; Xie et al., 2010; Zhang et al., 2010b), while Guo et al. (2001) calculated water interception as the interaction of the vegetation-soil-slope complex. Peng et al. (2008) estimated the vegetation benefit in storm runoff reduction by modelling the hydrological process under two different scenarios, one with the effect of tree cover and one with trees removed. The economic value of forest water-retention is usually estimated using either the price of water or the cost of storing water in manmade reservoirs. Water prices or hydroelectricity prices are used to represent water supply or water purification (Guo et al., 2001, 2007, 2008). The cost of artificial infrastructure, such as reservoirs, is used as a proxy for water regulation (Guo et al., 2008; Li et al., 2006; Peng et al., 2008; Xie et al., 2010; Xue and Tisdel, 2001; Zhang et al., 2010b). Guo et al. (2008) for example, estimated water regulation using the average cost of constructing unit volume of water reservoir according to national statistics. In addition, they also estimated water purification using the average price of domestic water use for national big and medium cities in 2007.

Table 2b Reviewed studies dealing with climate regulation, including their methodology, monetary value and size of study area.

Authors and geographical scope	Ecological functions assessment	Valuation method	Original estimate for study area ($x10^6$ RMB or USD)	Forested / Study area (km^2)	Estimate per hectare (Int USD 2013)
Guo et al., 2001 **Regional, Xingshan county**	C fixed by photosynthesis formula	Cost avoided for carbon fixation	RMB 46.45	1070/2316	158
Guo et al., 2001 **Regional, Xingshan county**	O2 supplied by photosynthesis formula	Cost avoided for oxygen	46.27 RMB	1070/2316	157
Guo et al., 2008 **National (pine forests)**	C fixed in forest	Cost avoided for marketed carbon	RMB 29700–30900**	NA/21900	4250–4422 **
Guo et al., 2008	O2 supplied by forest	Average price of			

National (pine forests)		oyxgen			
Hu et al., 2008 **Local, Menglun**	Land-use database	Benefit Transfer (Costanza et al., 1997)	USD 3.649–2.069***	NA/334	122- 69
Li et al., 2006 **Regional, Qinba mountains**	C fixed by photosynthesis formula	Cost/damage avoided for afforestation cost	RMB 35224.499	87089	1405
Li et al., 2006 **Regional, Qinba mountains**	O2 supplied by photosynthesis formula	Cost avoided for oxygen (industrial production)	RMB 37418.726	87089	1492
Niu et al., 2012 **National**	Amount of service performed*	Market price*	RMB 1500000	NA/2176986	1965
Peng et al., 2008 **Local, Nanjing (urban forest)**	C stored based on biomass	Cost avoided for afforestation	RMB 1.34	97/242	43
Li et al., 2010 **Local, Shenzhen**	Land-use database	Benefit Transfer (Costanza et al., 1997)	-	NA/1900	788–546
Xie et al., 2010 **Local, Beijing**	CO2 fixed by photosynthesis formula	Cost avoided for afforestation	RMB 3532.49	10500/16807	1014
Xie et al., 2010 **Local, Beijing**	O2 supplied by photosynthesis formula	Cost avoided for afforestation	RMB 2540.59	10500/16807	729
Xue and Tisdel, 2001 **Regional, Changbaishan mountain**	CO2 stored based on biomass	Cost avoided for afforestation	RMB 292.53	1670/1964	639

*Based on research station observations and published data

**Values refer to periods 1996–2000 and 2001–2005

*** Value refer to period 1988–2006

Climate change regulation

The volume of carbon and oxygen captured by forests is commonly estimated based on the photosynthesis and respiration formula (Guo et al., 2001; Li et al., 2006; Xie et al., 2010) or based on biomass (Peng et al., 2008; Xue and Tisdel 2001). The monetary value was estimated using either afforestation costs (Guo et al., 2001; Li et al., 2006; Xie et al., 2010) or applying the Swedish carbon tax rate (Guo et al., 2008). Alternatively, the cost of industrial oxygen production or other surrogate prices are used for estimating the value of oxygen (Guo et al., 2001; Guo et al., 2008; Li et al., 2006).

Table 2c Reviewed studies dealing with soil conservation, including their methodology, monetary value and size of study area.

Authors and geographical scope	Ecological functions assessment	Valuation method	Original estimate for study area ($x10^6$ RMB or USD)	Forested / Study area (km^2)	Estimate per hectare (Int USD 2013)
Guo et al., 2001 **Regional, Xingshan county**	Difference between forestland soil erosion and non-forestland soil erosion	Cost avoided for land disuse	RMB 2.94	1070/2316	10
Guo et al., 2001 **Regional, Xingshan county**	Difference between forestland soil erosion and non-forestland soil erosion	Cost avoided for removing silt accretion by manual labour	RMB 78.02	1070/2316	266
Guo et al., 2001 **Regional, Xingshan county**	Difference between forestland soil erosion and non-forestland soil	Cost avoided for water reservoir for decrease of soil deposit	RMB 50.38	1070/2316	172

	erosion				
Guo et al., 2001 **Regional, Xingshan county**	Difference between forestland soil erosion and non-forestland soil erosion	Market price of organic fertilizers	RMB 241.3	1070/2316	823
Guo et al., 2008 **National (pine forests)**	Difference between forestland soil erosion and non-forestland soil erosion	Cost avoided for artificial sediment removal	RMB 9100–8300**	NA/21900	1302–1187 **
Guo et al., 2008 **National (pine forests)**	Nutrient content in soil	Market price of organic fertilizers			
Hu et al., 2008 **Local, Menglun**	Land-use database	Benefit Transfer (Costanza et al., 1997)	USD 4.309–2.448 ***	NA/334	144–82
Hu et al., 2008 **Local, Menglun**	Land-use database	Benefit Transfer (Costanza et al., 1997)	USD 0,174–0,099***	NA/334	5–3
Li et al., 2006 **Qinmba mountains**	Difference between potential soil erosion and actual soil erosion	Cost avoided for land abandonment			
Li et al., 2006 **Regional, Qinba mountains**	Sediment accumulation capacity	Cost avoided for investment cost for water reservoir	RMB 2263.576	87089	90
Li et al., 2006 **Regional, Qinba mountains**	Nutrient content in soil	Market price of organic fertilizers			
Niu et al., 2012 **National**	Amount of service performed*	Market price*	RMB 900000	NA/2176986	1179
Li et al., 2010 **Local, Shenzhen**	Land-use database	Benefit Transfer (Costanza et al., 1997 and Xie et al., 2003)	-	NA/1900	1138–887
Xie et al., 2010 **Local, Beijing**	Soil conservation capacity	-	-	10500/16807	-
Xie et al., 2010 **Local, Beijing**	Soil bulk density and soil depth	Cost avoided for forestland	RMB 2.91	10500/16807	-
Xie et al., 2010 **Local, Beijing**	Soil bulk density and ratio of sediment deposition	Cost avoided for artificial sediment removal	RMB 4.51	10500/16807	1
Xue and Tisdel, 2001 **Regional, Changbaishan mountain**	Difference between woody land soil erosion and non-woody land soil erosion	Market price: net profit of forestry land for timber	RMB 2.2	1670/1964	-

*Based on research station observations and published data

**Values refer to periods 1996–2000 and 2001-2005

*** Value refer to period 1988–2006

Table 2d Reviewed studies dealing with nutrient cycling, including their methodology, monetary value and size of study area.

Authors and geographical scope	Ecological functions assessment	Valuation method	Original estimate for study area (x10^6 RMB or USD)	Forested / Study area (km^2)	Estimate per hectare (IntUSD 2013)
Guo et al., 2008 **National (pine forests)**	Nutrient accumulation in timber	Market price of organic fertilizers	RMB 3400–3500	NA/21900	486–500
Hu et al., 2008 **Menglun, Xishuangbanna**	Land-use database	Benefit Transfer (Costanza et al., 1997)	USD 15.071–8.540***	NA/334	505–286
Niu et al., 2012 **National**	Amount of service performed*	Market price*	RMB 200000	NA/2176986	262
Xie et al., 2010 **Local, Beijing**	Nutrient content in soil	Market price of organic fertilizers	RMB 351.45	10500/16807	100
Xie et al., 2010	Nutrient content in soil	Market price of organic	RMB 21.1	10500/16807	6

Local, Beijing		fertilizers			
Xue and Tisdel, 2001 **Regional, Changbaishan mountain**	Amount of nutrients mantained	Market price of organic fertilizers	RMB 43.39	1670/1964	94

*Based on research station observations and published data

**Values refer to periods 1996–2000 and 2001–2005

*** Value refer to period 1988–2006

Soil conservation and nutrient cycling

The valuation methods employed for soil conservation are perhaps the most varied across different studies in China. The methods to assess ecological functions include equations modelling soil properties (bulk density, soil depth) (Xie et al., 2010), estimating the soil erosion difference in forest and non-forestland (Guo et al., 2001; Guo et al., 2008; Xue and Tisdel, 2001) and deriving the difference between potential and actual soil erosion based on rain pattern, soil erosion and soil conservation rates, slope and vegetation cover (Li et al., 2006). The cost of artificial sediment removal was employed to obtain the monetary value of erosion control in forestland (Guo et al., 2001; Guo et al., 2008; Xie et al., 2010). For example, Guo et al. (2008) used the cost for digging and transporting a unit volume of soil. Instead, Li et al. (2006) used the cost for artificial water storage as a proxy of sediment accumulation, based on the fact that in major Chinese valleys 24% of sediments accumulate in reservoirs. Some authors also took into account the ‘avoided abandoned land’ as in the beneficial effect that forests have in maintaining soil and avoiding land disuse, calculated as the area of land conserved and the average thickness of surface soil multiplied by the opportunity cost of forest. However, it is not always clear what proxy is used for the opportunity cost. Xie et al. (2010) used the ‘replacement price method for forestland’, while Guo et al. (2001) used ‘forestry economic profit’. Xue and Tisdel (2001) specify opportunity cost as the net profit for timber production in forestland. Several authors estimated the value of nutrient maintenance or accumulation by forest systems based on the nutrient content in soil or even in timber (nitrogen, phosphorous and potassium) multiplied by the price of synthetic nutrients or fertilizers. It is therefore worth noticing that estimating the nutrient value in timber might lead to double counting with the production value of timber.

Other ecosystem services

The monetary value of air purification is calculated as the amount of pollutants retained by forests (e.g. sulfur dioxide, nitrogen dioxide, dust) and aero-anions and even phytoncide (an anti-microbial compound) released into the environment (Guo et al., 2008; Xie et al., 2010) multiplied by the avoided cost of artificial air purification, such as the price for cleaning precipitated dust (Guo et al., 2008). Values of food, timber and raw materials are calculated based on annual production and market prices (Xie et al., 2010). Values of recreation, amenity and other cultural services are assessed using contingent valuation (Jim and Chen, 2006) or statistics on tourism income (Xie et al., 2010).

3.2 Monetary estimates of ecosystem services

The estimated per hectare values for hydrological services from China vary widely, from a few dollars to several thousand (Table 3). This variation is partly determined by the different methods employed for calculations. The lowest estimate is found in Guo et al., (2001) (USD 12/ha) when using the market price of water for consumption. The paper estimated the value of water for hydropower purposes in the same county of Xingshan to be at USD 154/ha. The highest values for hydrological services are found in studies covering the entire country (almost USD 5000/ha) (Guo et al., 2008; Niu et al., 2012). Monetary values for climate regulation were found to range between USD 43/ha and more than USD 4000/ha. The minimum value is found in Local, Nanjing (urban forest) (Peng et al., 2008), while the maximum values were again found in studies based on national-level data (Guo et al., 2008; Niu et al., 2012). The values of carbon sequestration and greenhouse gas regulation vary widely both nationally and globally, since they are highly sensitive to the price used to value these services. Most estimates for soil conservation are meant, in the original papers, to be coupled with other soil-related services (e.g. nutrient cycling) and are to be considered complementary to these. For this reason some values are very low (e.g. USD 1/ha, Xie et al., 2010), whereas the highest estimate is over USD 1000/ha (Guo et al., 2008). Values for nutrient cycling are found to range between USD 6/ha and over USD 500/ha. The lowest estimate (reduction of sediment deposition) is meant to be coupled with the nutrient value accumulated in vegetation (USD 100/ha). The total economic value of Chinese forests was calculated by Chen and Zhang (2000) and Niu et al. (2012); in several provinces, they observed a decoupling between the values of forest ecosystem services and the gross domestic product (GDP). In both studies, the monetary value of forests was estimated to be about 30% of GDP.

Table 3 A comparison of monetary values from reviewed Chinese studies (IntUSD 2013 / ha) and existing global monetary estimates from Ninan and Inoue (2013) (Int USD 2010 / ha) for the following forest ecosystem services: hydrological services, carbon storage, soil conservation and nutrient cycling.

	Global (Ninan and Inoue 2013)	China

	Monetary estimates (Int USD 2010 / ha)		No Studies	Monetary estimates (Int USD 2013 / ha)		No Studies
	min	max		min	max	
Hydrological services	5	1160	18	12	4938	9
Carbon storage	36	3500	14	4	4422	9
Soil conservation	1	1000	5	3	1302	8
Nutrient cycling	5	500	2	56	505	6

To sum up, the reviewed literature from China shows a wide variation in the monetary estimates for forest ecosystem services. The range of values is, however, in the same order of magnitude as the existing global estimates for forest ecosystem services from Ninan and Inoue (2013). For exa mple, the values for carbon storage, soil conservation and nutrient cycling in Chinese forests are found to be very similar to global-level estimates. Instead, estimates for hydrological services in China are somewhat higher than global values (respectively USD 4938/ha and 1160/ha).

4. Discussion and conclusions

This paper reviewed existing scientific articles published in English dealing with the monetary valuation of forest ecosystem services in China. According to previous reviews, there is a great abundance of domestic scientific research on monetary valuation in China (Ninan and Inoue, 2013; Liu and Costanza, 2010). However, it was not feasible for us to systematically assess the amount of domestic literature; we did not find any existing census of or systematic review on the domestic literature either. Based on our review, the volume and coverage of monetary valuation of forest ecosystems in China available in English in peer-reviewed journals is still modest, and quantitative inferences based on it are therefore only tentative. However, several research areas for future studies can be identified. The 12 studies identified in our review were found to deal most often with regulating services, especially hydrological services, carbon storage (or, complementary, oxygen release), soil conservation and nutrient cycling. The methodological approaches employed appeared to vary, from the use of benefit transfer to market price and cost avoided method. Great differences in the selection of indicators, calculation approaches and reference prices between studies have already been registered in a previous literature review (Zhang et al., 2010a).

Based on our analysis we conclude that only a few papers actually provide monetary estimates of ecosystem services per unit of area, especially when considering the single ecosystem services investigated, rather than the total value (or ‘bundle’) of ecosystem services. However, drawing comparisons and inferences based on total values of ecosystem services is not fruitful, since different studies deal with different-sized areas. Our analysis of the ‘per unit area’ monetary values shows a great variation in the estimates of each ecosystem service. Similar variation is also found in previous research for global estimates (e.g. de Groot et al., 2012; Ninan and Inoue, 2013). It is not possible, based on our analysis, to deduce how much the chosen methodology influences the monetary estimate of ecosystem services. Some of the identified variation is likely due to the context-dependency of ecosystem services and related values, i.e. it derives from the geographical, ecological and socio-economic diversity of the study locations. The conversion of monetary values to international currency USD (see methods section) addresses the effect of inflation across different years. Much of the variation is likely due to the different methodological approaches used, as already suggested in de Groot et al. (2012).

Furthermore, several papers do not define well the concept of ecosystem services under investigation. Consequently, categorization and definition of the ecosystem services investigated is elusive and hampers any attempt of comparative analysis between different studies. Another common problem is that sometimes two or more services with different outputs are jointly valued. Zhang et al. (2010a) have stressed the need to first adopt a unified definition of ecosystem services as well as recommend using only standardized methodologies for valuating ecosystem services. When designing future valuation studies for China, more attention should be paid to clearly defining ecosystem services and/or explicitly adopting internationally recognized classifications (e.g. MA or CICES), or frameworks available at national level (e.g. State Forestry Administration of China, 2008). However, as Ojea et al. (2012) pointed out, even the use of the MA classification can raise several conceptual and technical difficulties when dealing with monetary values of forest ecosystem services. The definition of ecosystem services especially relates to the motivation for mobilizing ecosystem services (Fisher et al., 2009) and with the specific study goals (e.g. awareness raising, informing a specific policy context, developing accounting systems, or analysing changes or different options for land-use and management). The problem of a clearly defined and coherent classification of ecosystem services, however, has not yet been fully tackled by the theoretical literature, especially for a comprehensive operational framework. The impossibility to distil a universal and yet comprehensive checklist of ecosystem services (Haines-Young and Potschin, 2010) remains a main problem for comparability among monetary valuation studies.

It is also important to strengthen the methodology underpinning the ecological and monetary valuation of ecosystem services (Table 4). The underlining assumption when using the benefit transfer method is the similarity between sites in terms of ecological, social and economic aspects.

An indiscriminate application of the benefit transfer could produce quick, but unsound values. As stressed in Kettunen and ten Brink (2013, p. 41), eventual differences between the investigated study site and the site from which the original value was taken can and should be ‘corrected’ for. For example, in Xie et al. (2003), a coefficient was used to adjust the monetary values drawn from Costanza et al. (1997). This can be done, for example, by having experts or other stakeholders assigning relative weights to the original monetary value in order to adjust it for the local context. The use of valuation methods other than benefit transfer (market price, cost avoided method, stated or revealed preferences) is directly connected to the local, site-specific ecological functions performed by the ecosystem under investigation. Such methods are however, more time consuming than conducting benefit transfer, and some methodological challenges remain unattended. One problem is how to quantify the ecological functions and to choose appropriate monetary values, which requires an interdisciplinary approach. Boyd and Banzhaf (2007) stressed the need for consistently defined unit of account to measure ecosystem services; this includes identifying and estimate ‘quantity’ and prices of ecosystem services. Regarding the ‘quantity’, one challenge is the distinction between intermediate and final services (Bateman et al., 2010; Fisher, 2008). This practice is essential to avoid double counting, of which regulating and supporting services are especially susceptible. For example, as oxygen and carbon dioxide can be considered joint products of the same process, it was argued (Xue and Tisdel, 2001) that aggregating the economic value of both might lead to double counting (e.g. Guo et al., 2001; Li et al., 2001). Another issue is to isolate the human contribution from the ecosystem service input. This problem occurs, for example, when estimating the value of fruit or timber (e.g. Xie et al., 2010) as market price approach does not exclude the human input of harvesting. Furthermore, few of the reviewed articles made a distinction between different vegetation types in analysing ecosystem services value. Zhang et al., (2010b) estimated the water conservation capacity of forest ecosystems in Beijing based on forest type, including over 10 dominant species of coniferous, broadleaf, mixed and shrub forests. Niu et al., (2012) used a combination of measurement data from *in loco* research stations and remote sensing to develop an analysis based on trees’ age-class stands.

Challenges also exist for the choice of appropriate prices for ecosystem services. For example, what is the most appropriate price for carbon retention or for hydrological services? Previous literature (e.g. Ferraro et al., 2012) has highlighted some inaccuracies that occur with market prices and cost avoided method. It is arguable, for instance, whether market prices or cost of artificial water infrastructures really relate to the value of the ecosystem service. Water or hydroelectricity prices are subject to seasonal variation and use type, such as household, commercial, industrial and irrigation.

The cost avoided method additionally needs to take into account the lifespan of reservoirs, the direct costs of dam construction and maintenance, as well as the indirect costs of storing water. Regarding climate regulation, for example, the use of the Swedish carbon tax rate was criticized as unfit for calculating the carbon sequestration value of ecosystems in China (Zhang et al., 2010). A possible alternative for carbon price could lay in the pilot emission trading schemes that are being introduced locally in China, with possible development of a nation-wide scheme (Lo, 2013). Even if the schemes are implemented, this solution still presents challenges, for example whether the carbon price would actually reflect the production or social cost of carbon.

Table 4 A summary of the main conceptual and methodological challenges to monetary valuation, drawn from Bateman et al. (2010); Boyd and Banzhaf (2007); Kettunen and ten Brink (2013); Pagiola et al. (2004); TEEB (2010).

Method	**Description**	**Limitations**	**Advantages**
Market price	Market price is employed to calculate the value of an ecosystem service. Appropriate prices should be selected and corrected in case of e.g. market distortion and non-competitive prices.	Mainly applicable to the 'goods'.	Data relatively easy to obtain. Context specific values.
Avoided cost method	Cost of replacing an ecosystem service with an artificial alternative. Appropriate costs should be selected.	Risk of overestimating the actual value. Data, resources and inter-disciplinary approach needed.	Relevant in estimating regulating services. Context specific values.
Contingent valuation	Elicitation of willingness-to-pay for an ecosystem service from respondents.	Potential sources of bias in responses. Non-commensurability of non-use values.	Relevant in estimating non-use values. Context specific values.
Benefit Transfer	Land use is employed as a proxy for changes in ecosystem services. Ecological similarity between primary and secondary study sites is assumed. Eventual social and economic differences between the primary and secondary study sites that might influence ecosystem services' value should be accounted and corrected for.	Values are not context specific; lack of studies from which to draw suitable estimates.	Enhances the usefulness of available literature; little data and resources needed; allows easy assessment of marginal values.

Finally, there is the issue of distinguishing between stock and flow of ecosystem services. The relevant theoretical literature hosts a diversity of opinions on the definition of stock and flow, which also influences the choice of proxies or indicators for respective ecosystem services (e.g. Bateman et al., 2010; Boyd and Banzhaf 2007; Fisher, 2008; Wallace, 2007). These authors agree, however, that the stock is the amount of ecosystem assets at a given point of time, and it is measured as a physical quantity; a flow is measured as a production during a certain assessment period. Based on our review, the main body of research available in English on forests of China is often a static analysis of ecosystem service values in specific locations. The assessment of marginal values (i.e. over a time period or space) is not sufficiently addressed in terms of time frame, characteristics and forestland quality (species composition, management). In addition, none of the reviewed studies dealt with scenario analysis based on different land use options. Most studies also lack sensitivity analysis dealing with uncertainties of the results. As a consequence, despite their original goal, only a few studies actually seem to have strong research applications or policy relevance. This has been observed also in studies worldwide (Ferraro et al., 2012; Fisher et al., 2008). Given the discussed problems and challenges of monetary valuation, very few primary studies qualify to extrapolate and standardize monetary values for secondary uses and applications. For example, the Ecosystem Service Value Database (ESDV) (van de Ploegt al., 2010) only includes two case studies from Chinese forests (tropical, temperate and boreal forests + woodland), out of 25 from the Asian continent, and against 8 from the USA. This calls for a careful consideration, prior to study design, of potential secondary uses and applications of monetary valuation studies.

In addition to clarifying definitions and classifications, and choose appropriate indicators, one important approach is to map ecosystem services in a spatially explicit way across a region (Steffen, 2009). This can contribute to 1) highlight areas of ecosystem services trade-offs; 2) identifying and involving stakeholders (e.g. experts, local communities) in the quantification and governance of ecosystem services. This involves the development of geospatial technologies and ecological modeling at different administrative levels, an area of research that can count on long-term data in China. In light of the global policy- and economy- driven land use changes (e.g. expanding plantation area), regional monetary valuation using robust methodology should be an area of interest for research. Ecological functions in plantations are structurally and functionally different from those of natural forests, including for example water balance, soil erosion and carbon sequestration. Some assessments have recognized the Total Economic Value (TEV) of plantations to be lower than the average TEV of native forests (Bauhus et al., 2010, p. 29; Fisher et al., 2008). However, globally there is a complete lack of studies estimating the monetary value of forest ecosystem services in plantations. In this context, future research on monetary valuation could importantly contribute to support the policy needs to distinguish between different types of forests, as well as for the need of assessing a range of policy and management options. Future research, for example in the context of the forthcoming TEEB China[1], could also benefit from a focus on benefit flows across different stakeholders. This also links to the observed a decoupling between the values of forest ecosystem services and the gross domestic product (GDP) (Chen and Zhang, 2000; Niu et al., 2012). It would be interesting, for example, to investigate how forest ecosystem services contribute to local communities' livelihood in underdeveloped regions. This can include for example provisioning services, such as collection of timber and raw materials; cultural services, such as the value of tourism and recreation in forests; and wider socio-economic benefits, such as employment, income and local development. Assessing monetary values of ecosystem services is propaedeutic to inform correct decision making, including, for example, the establishment of ecological compensations.

In conclusion, the existing valuation studies on forest ecosystems in China appear to suffer from similar problems to the ones found in international literature: elusive categorization and methodological inconsistencies. The work of interdisciplinary research is then fundamental in continuing to develop the conceptual framework of ecosystem services, especially from a valuation / accounting perspective. Based on this review, very few Chinese studies are available in English for the international research community, thus qualifying for secondary uses and applications. Even though hampered by the language barrier, domestic research can however count on some means to further develop in this area. First, national ecological research stations and networks – such as the Chinese Ecosystem Research Network (CERN) and the Chinese Forest Ecosystem Research Network (CFERN) – that are involved in long-term research with emphasis on nutrient and energy flows at the ecosystem level (Zhang et al., 2010a). Second, national yearbooks and statistics from which to draw relevant indicators (e.g. Guo et al., 2008; Niu et al., 2012). Finally, the exceptional policy landscape related to forest conservation and payments for ecosystem services (e.g. Yin et al., 2014) and the rapid development of forestry and industrial plantations in China (Zhang et al., 2015) offer important application opportunities for research on the monetary valuation of forest ecosystem services.

Acknowledgements

We wish to thank Stella Thompson for the language revision of this article. Financial support from Academy of Finland grant 1265593 is also gratefully acknowledged.

---

[1] The Economics of Ecosystems and Biodiversity (TEEB) is a global initiative aimed at drawing the attention of the scientific and political community to the economic benefits of biodiversity and ecosystem services and the cost of their loss and degradation (TEEB, 2015). The Chinese government has signaled its support for a future TEEB national study (UNEP, 2012)

References

Bateman, I.J., Fezzi, Grace G.M., Atkinson, C. Turner, G.K., 2010. Economic analysis for ecosystem service assessments. Environ. Resource Econ. 48(2), 177–218. Doi: 10.1007/s10640-010-9418-x.

Bauhus, J., Van Der Meer, P. Kanninen, M., 2010. Ecosystem goods and services from plantation forests. Earthscan. ISBN: 978-1-84971-168-5.

Bennett, M.T., 2009. Markets for ecosystem services in China: an exploration of China's eco-compensation and other market-based environmental policies. Forest Trends. ISBN 1-932928-39-1.

Boyd, J., Banzhaf, S., 2007. What are ecosystem services? The need for standardized environmental accounting units. Ecol. Econ. 63(2-3), 616-626. Doi:10.1016/j.ecolecon.2007.01.002.

Brown, S., 2002. Measuring carbon in forests: current status and future challenges. Environ. Pollut. 116, 363–372.

Chen, Z., Zhang, X., 2000. Value of ecosystem services in China. Chin. Sci. Bull. 45(10), 870-876. Doi: 10.1007/BF02886190.

CICES – Common International Classification of Ecosystem Services, 2015, April 16. Available at: http://cices.eu.

Costanza, R., d'Arge, R., de Groot, R., Farber, S., Grasso, M., Hannon, B., Naeem, S., Limburg, K., Paruelo, J., O'Neill, R., Raskin, R., Sutton, P., van denBelt, M., 1997. The value of the world's ecosystem services and natural capital. Nature 387, 253-260. Doi: 10.1016/j.ecoser.2012.07.005.

D'Amato, D., Li, N, Rekola, M, Toppinen, Lu, F-F., 2015. Linking forest ecosystem services to corporate sustainability disclosure: A conceptual analysis. Ecos. Serv. In press. Doi:10.1016/j.ecoser.2014.11.017.

de Groot, R., Brander, L., Ploeg, S., Costanza, R., Bernard, F., Braat, L., Christie, M., Crossman, N., Ghermandi, A., Hein, L., Hussain, S., Kumar, P., McVittie, A., Portela, R., Rodriguez, L., tenBrink, P., vanBeukering, P., 2012. Global estimates of the value of ecosystems and their services in monetary units. Ecos. Serv. 1(1), 50-61. Doi:10.1016/j.ecoser.2012.07.005.

Durst, P.B., Waggener, T.R., Enters, T. Cheng, T.L., 2001. Forests out of bounds: Impacts and effectiveness of logging bans in natural forests in Asia-Pacific. Food and Agricultural Organization of the United Nations Regional Office for Asia and the Pacific Bangkok, Thailand.

Evans, J., 2009. Planted forests: uses, impacts and sustainability. Published jointly by CAP international and FAO.

Fang, J.Y., Chen, A.P., Peng, C.H., Zhao, S.Q., Ci, L.J., 2001. Changes in forest biomass carbon storage in China between 1949 and 1998. Science 292, 2320–2322.

FAO - Food and Agriculture Organization of the United Nations, 2015, March 24. Faostat. Available at: http://faostat.fao.org/default.aspx.

Ferraro, P.J., Lawlor, K., Mullan, K.L. Pattanayak, S., K., 2012. Forest figures: Ecosystem services valuation and policy evaluation in developing countries. *Rev.* Environ. Econ. Policy 6(1), 20 - 44. Doi: 10.1093/reep/rer019.

Fisher, B., Turner, R. K. Morling, P., 2009. Defining and classifying ecosystem services for decision making. Ecol. Econ. 68(3), 643–653. Doi:10.1016/j.ecolecon.2008.09.014.

Fisher, B., 2008. Ecosystem services: classification for valuation. Ecol. Econ. 141(5), 1167-1169. Doi:10.1016/j.biocon.2008.02.019.

Fisher, B., Turner, K., Zylstra, M., Brouwer, R., de Groot, R., Farber, S., Ferraro, P., Green, R., Hadley, D., Harlow, J., Jefferiss, P., Kirby, C., Morling, P., Mowatt, S., Naidoo, R., Paavola, J., Strassburg, B., Yu, D., Balmford, A., 2008. Ecosystem services and economic theory: integration for policy-relevant research. Ecol. Appl. 18(8), 2050-2067. Doi: http://dx.doi.org/10.1890/07-1537.1.

Gómez-Baggethun, Pérez, M., 2011. Economic valuation and the commodification of ecosystem services. Prog. Phys. Geogr. 35(5), 613-628. Doi: 10.1177/0309133311421708.

Guo, H., Wang, B., Ma, X., Zhao, G., Li, S., 2008. Evaluation of ecosystem services of Chinese pine forests in China. Sci. China Ser. *C* 51(7), 662-670. Doi: 10.1007/s11427-008-0083-z.

Guo, Z., Xiao, Z., Gan, Y., Zheng, Y., 2001. Ecosystem functions, services and their values – a case study in Xiangshan County of China. Ecol. Econ. 38, 141-154. Doi:10.1016/S0921-8009(01)00154-9.

Haines-Young, R., Potschin, M., 2010. The links between biodiversity, ecosystem services and human well-being. In: Raffaelli, D., Christopher, L.J.F., (Eds.) Ecosystem Ecology: a new synthesis. BES Ecological Reviews Series, CUP, Cambridge, pp. 110-139.

Hansen, E., Panwar, R., Vlosky, R., 2014. The Global Forest Sector. Changes, Practices and Prospects. Taylor and Francis Group, LCC.

Hu, H., Liu, W., Cao, M., 2008. Impact of land-use and land-cover changes on ecosystem services in Menglun, Xishuangbanna, Southwest China. Environ. Monit. Assess.146(1-3), 147-156.

Jim, C.Y., Chen, W.Y., 2006. Recreation–amenity use and contingent valuation of urban greenspaces in Guangzhou, China. Landsc. Urban. Plan. 75(1-2), 81–96.

Khan, K.S., Kunz, R., Kleijnen, J., Antes, G., 2003. Five steps to conducting a systematic review. J. R. Soc. Med. 96(3), 118–121.

Kettunen, M., ten Brink, P., 2013. The Social and Economic Benefits of Protected Areas: An Assessment Guide. Earthscan / Taylor & Francis Group.

Li, J., R., Z., Zhou, Z., 2006. Ecosystem services and their values: a case study in the Regional, Qinba mountains of China. Ecol. Res. 21(4), 597-604.

Li, T., Li, W., Qian, Z., 2010. Variation in ecosystem service value in response to land use changes in Local, Shenzhen. Ecol. Econ. 69(7), 1427-1435. Doi:10.1016/j.ecolecon.2008.05.018.

Liu, S., Costanza, R., 2010. Ecosystem services valuation in China. Ecol. Econ. 69(7), 1387-1388. Doi:10.1016/j.ecolecon.2010.03.010.

Liu, J.G., Li, S.X, Ouyang, Z.Y, Tams, C., Chen, X.D., 2008. Ecological and socioeconomic effects of China's policies for ecosystem services. PNAS 105(28), 9477–9482. Doi: 10.1073/pnas.0706436105.

Lo, A.Y., 2013. Carbon trading in a socialist market economy: Can China make a difference? Ecol. Econ. 87, 72–74. Doi:10.1016/j.ecolecon.2012.12.023.

Luck, G.W., Chan, K.M.A., Eser, U., Gómez-Baggethun, E., Matzdorf, B., Norton, B. and Potschin, M.B., 2012. Ethical Considerations in On-Ground Applications of the Ecosystem Services Concept. BioScience 62(12), 1020 - 1029. Doi: 10.1525/bio.2012.62.12.4.

MA – Millennium Ecosystem Assessment, 2005. Ecosystems and Human Well-being: Biodiversity Synthesis, World Resources Institute.

Madsen, B., Carroll, N., Brands, K.M., 2010. State of biodiversity markets report: Offset and compensation programs worldwide. Ecosystem Marketplace. Washington, DC.

Ninan, K.N., Inoue, M., 2013. Valuing forest ecosystem services: What we know and what we don't. Ecol. Econ. 93, 137-149. Doi:10.1016/j.ecolecon.2013.05.005.

Niu, X., Wang, B., Liu, S., Kiu, C., Wei, W., Kauppi, P.E., 2012. Economical assessment of forest ecosystem services in China: Characteristics and implications. Ecol. Complex. 11, 1–11. Doi:10.1016/j.ecocom.2012.01.001.

Ojea, E., Martin-Ortega, J., Chiabai, A., 2012. Defining and classifying ecosystem services for economic valuation: the case of forest water services. Environ. Sci. Policy 19-20, 1-5. Doi:10.1016/j.envsci.2012.02.002.

Pagiola, S., von Ritter, K., Bishop, J., 2004. How much is an ecosystem worth? Assessing the economic value of conservation. Washington, DC. The World Bank.

Pawson, S.M., Brin, A., Brockerhoff, E.G., Lamb, D., Payn, T.W., Paquette, A., Parrotta, J.A. , 2013. Plantation forests, climate change and biodiversity. Biodivers. Conserv. 22: 1203-1227. Doi:10.1007/s10531-0130458-8.

Peng, L., Chen, S., Liu, Y., Wang, J., 2008. Application of CITYgreen model in benefit assessment of Local, Nanjing (urban forest) in carbon fixation and runoff reduction. Front. Forest. China 3(2), 177-182.

Riera, P., Signorello, G., Thiene, M., Mahieu, P. A., Navrud, S., Kaval, P., Rulleau, B., Mavsar, R., Madureira, L., Meyerhoff, J., Elsasser, P., Notaro, S., De Salvo, M., Giergiczny, M., Dragoi, S., 2012. Non-market valuation of forest goods and services: Good practice guidelines. J. For. Econ. 18(4), 259–270. Doi:10.1016/j.jfe.2012.07.001.

Spangenberg, J. H., Settele, J., 2010. Precisely incorrect? Monetising the value of ecosystem services. Ecol. Complex. 7(3), 327–337. Doi:10.1016/j.ecocom.2010.04.007.

State Forestry Administration of China, 2008. Specifications for Assessment of Forest Ecosystem Services in China. Standards Press of China, Local, Beijing.

Steffen, W., 2012. Interdisciplinary research for managing ecosystem services. PNAS 106(5), 1301–1302.

TEEB – The Economics of Ecosystem and Biodiversity, 2012, The Economics of Ecosystems and Biodiversity in Business and Enterprise. Joshua Bishop (Ed.). Earthscan, London and New York.

TEEB – The Economics of Ecosystem and Biodiversity, 2010, The Economics of Ecosystems and Biodiversity: Ecological and Economic Foundations. Pushpam Kumar (Ed.). Earthscan, London and Washington.

The World Bank, 2015, January 18. Available at: http://www.worldbank.org.

Turnbull, J.W. 2007. Development of sustainable forestry plantations in China: a review. Impact Assessment Series Report No. Australian Centre for International Agricultural Research.

Turner, R.K., Morse-Jones, S., Fisher, B., 2010. Ecosystem valuation, a sequential decision support system and quality assessment issues. Ann. *N. Y.* Acad. Sci. 1185, 79–101.

UNEP – United Nations Environment Programme, 2012, July 12. China Voices Support for National Study on Value of Ecosystem Services - Available at: http://www.unep.org/newscentre/Default.aspx?DocumentId=2691&ArticleId=9238.

van der Ploeg, S., de Groot, D., Wang, Y., 2010. TEEB Valuation Database: overview of structure, data and results. Foundation for Sustainable Development.

Wallace, K.J., 2007. Classification of ecosystem services: Problems and solutions. Biol. Cons(3-4). 139, 235-246. doi:10.1016/j.biocon.2007.07.015.

Wilson, M. A., Howarth, R. B., 2002. Discourse-based valuation of ecosystem services: establishing fair outcomes through group deliberation. Ecol. Econ. 41(3), 431–443. Doi:10.1016/S0921-8009(02)00092-7.

Xie, G., Li, W., Xiao, Y., Zhang, B., Lu, C., An, K., Wang, J., Xu, K., Wang, J., 2010. Forest ecosystem services and their values in Local, Beijing. Chin. Geogr. Sci. 20(1), 51-58. Doi: 10.1007/s11769-010-0051-y.

Xu, D.P., Bai J.Y., Dell, B., 2000. Overcoming the constraints to productivity of plantation eucalypts in Southern China. In: Gong, M.Q., Xu, D.P., Zhong, C.L., Chen, Y.L., Dell, B., Brundrett, M., (Eds.) Proceedings of ACIAR Workshop on Mycorrhiza, Guangzhou, China.

Xu, J., Yin, R., Li, Z., Liu, C., 2006. China's ecological rehabilitation: Unprecedented efforts, dramatic impacts, and requisite policies. Ecol. Econ. 57(4), 595-607.

Xue, D., Tisdel, C., 2001. Valuing ecological functions of biodiversity in Changbaisha Mountain Biosphere Reserve in Northeast China. Biodivers. Conserv. 10(3), 467-481.

Yang, X., Wang, X., Li, N., 2010. Combating Climate Change: What Will China's Forestry Industry Do? Ambio 39(4), 340–343.

Yin, R.S., Liu, C.; Zhao, M.J., Yao, S.B., Liu, H., 2014. The implementation and impacts of China's largest payment for ecosystem services program as revealed by longitudinal household data. Land Use Policy 40, 45-55.

Yukuan, W., Bin, F., Colvin, C., Ennaanay, D., McKenzie, E., Min, C., 2010. Mapping conservation areas for ecosystem services in land-use planning, China. Available at: TEEBweb.org.

Zhang, Y., Luo, W., Toppinen, A., 2015. Determinants of Equity-Based Entry Mode Choice in the Forest sector: the Case of China. Scand. J. Fore. Res. 30(1), 3-12.

Zhang, B., Li, W., Xie, G., 2010a. Ecosystem services research in China: Progress and perspective. Ecol. Econ. 69(7), 1389–1395. Doi: 10.1016/j.ecolecon.2010.03.009.

Zhang, B., Li, W., Xie, G., Xiao, Y., 2010b. Water conservation of forest ecosystem in Local, Beijing and its value. Ecol. Econ. 69(7), 1416-1426. Doi:10.1016/j.ecolecon.2008.09.004.

Zhao, M., Zhou, G.S., 2005. Estimation of biomass and net primary productivity of major planted forests in China based on forest inventory data. Forest Ecol. Manag. 207, 295–313.

Zhen, L., Zhang, H.Y., 2011. Payment for ecosystem services in China: An overview. LRLR 5(2). Doi: 10.12942/lrlr-2011-2.